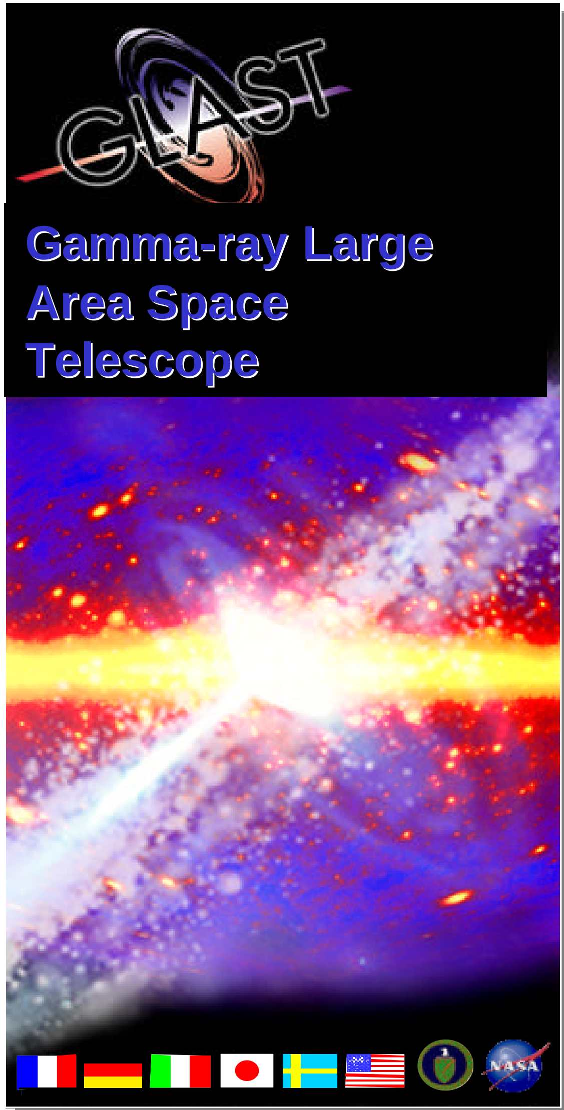

GLAST Large Area Telescope:

Dual PIN Photodiode Issues
Calorimeter Subsystem

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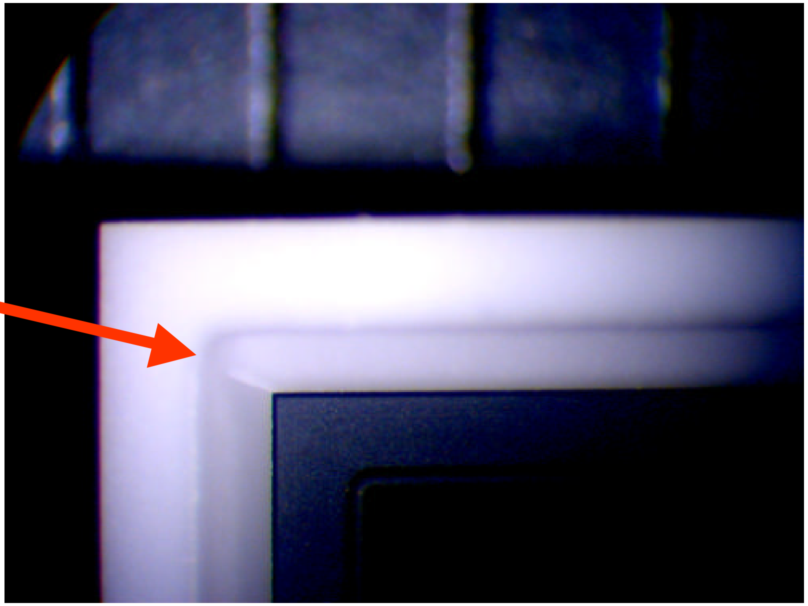
Dual PIN Photodiode Qualification

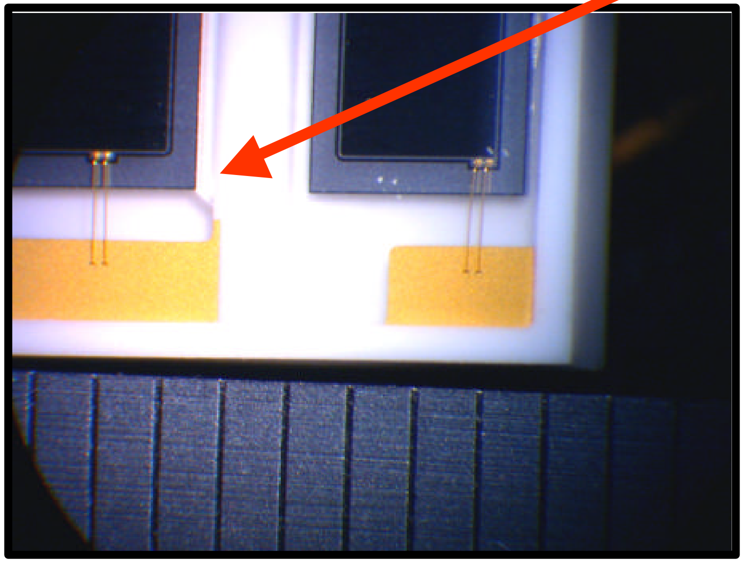
Qualification testing in France and US of DPD indicate problems with extended thermal cycling.

- (NRL) micro-cracking in optical epoxy detected in test samples after ~50 thermal cycles at qualification temperature extremes (-30°C, +50 °C at 0.3 deg/min).
  - No degradation in optical or electrical performance have been detected with presence of micro-cracking, even after 100 thermal cycles.
- (France) Serma Technologies evaluation of diode discovered catastrophic cracking and delamination of optical epoxy in various thermal cycling tests.
  - Typical rate of change was 1 – 2 deg/min in cycling.
  - 2nd evaluation at Serma showed no correlation with humidity absorption prior to testing.
  - 4 units failed electrically. Subsequent investigation indicated that the wire bonds were broken. (Epoxy shrinkage or shearing?)

Dual PIN Diode Temperature Cycling

After ~ 50 thermal cycles (-30,+50 deg C) small cracks develop in optical epoxy radiating out from the edge of the Si die. These are at the depth of the Si and descend to base of ceramic (x20 magnification).





No change in electrical or optical properties

NRL testing at 0.3 deg/min

Thermal Cycling Tests at NRL

- **Sample 1: 8 bare S8576 diodes**
  - **Summer '01 shipment, lot 1G**
  - **-30C to +50C, 20 deg per hour, 1 hr soaks; >50 cycles**
  - **Dry nitrogen purge, rapid but unmeasured flow rate**
  - **Diode leads stuck in conductive foam, placed on wire mesh platform away from chamber walls**
  - **Results: some with microcracks; some with no obvious changes**
- **Sample 2: 29 S8576 diodes bonded to CsI**
  - **Summer '01 shipment, lot 1G**
  - **-30C to +50C, 20 deg per hour, 1 hr soaks; >50 cycles**
  - **Dry nitrogen purge, rapid but unmeasured flow rate**
  - **Diodes bonded to CsI xtals (> 27 cm^3 of CsI each) with Dow Corning DC93-500 silicone elastomer encapsulant**
  - **Results: detailed visual inspections not yet completed**
    - **Prelim visual inspection shows no severe cracks, several with microcracks, several with no obvious changes**
    - **several destroyed in bond strength test prior to inspection**

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Thermal Cycling Tests at NRL (2)

- **Sample 3: 10 bare S8576 diodes**
  - **Spring ’02 shipments, lots 2B and 2C**
  - **-30C to +50C, 5 deg per *minute*, 30 minute soaks; 46 cycles**
  - **Dry nitrogen purge, rapid but unmeasured flow rate**
  - **Diodes stuck in conductive foam, placed on wire mesh platform away from chamber walls**
  - **Results: 1 with severe crack; 9 no obvious changes**
- **Sample 4: 10 bare S3590-01 diodes**
  - **Non-functioning mechanical samples, received Spring ‘02**
  - **-30C to +50C, 5 deg per *minute*, 30 minute soaks; 46 cycles**
  - **Dry nitrogen purge, rapid but unmeasured flow rate**
  - **Diodes stuck in conductive foam, placed on wire mesh platform away from chamber walls**
  - **Results: 6 with severe peeling of resin from ceramic; 2 with delamination above bonding pads; 3 with no obvious changes**

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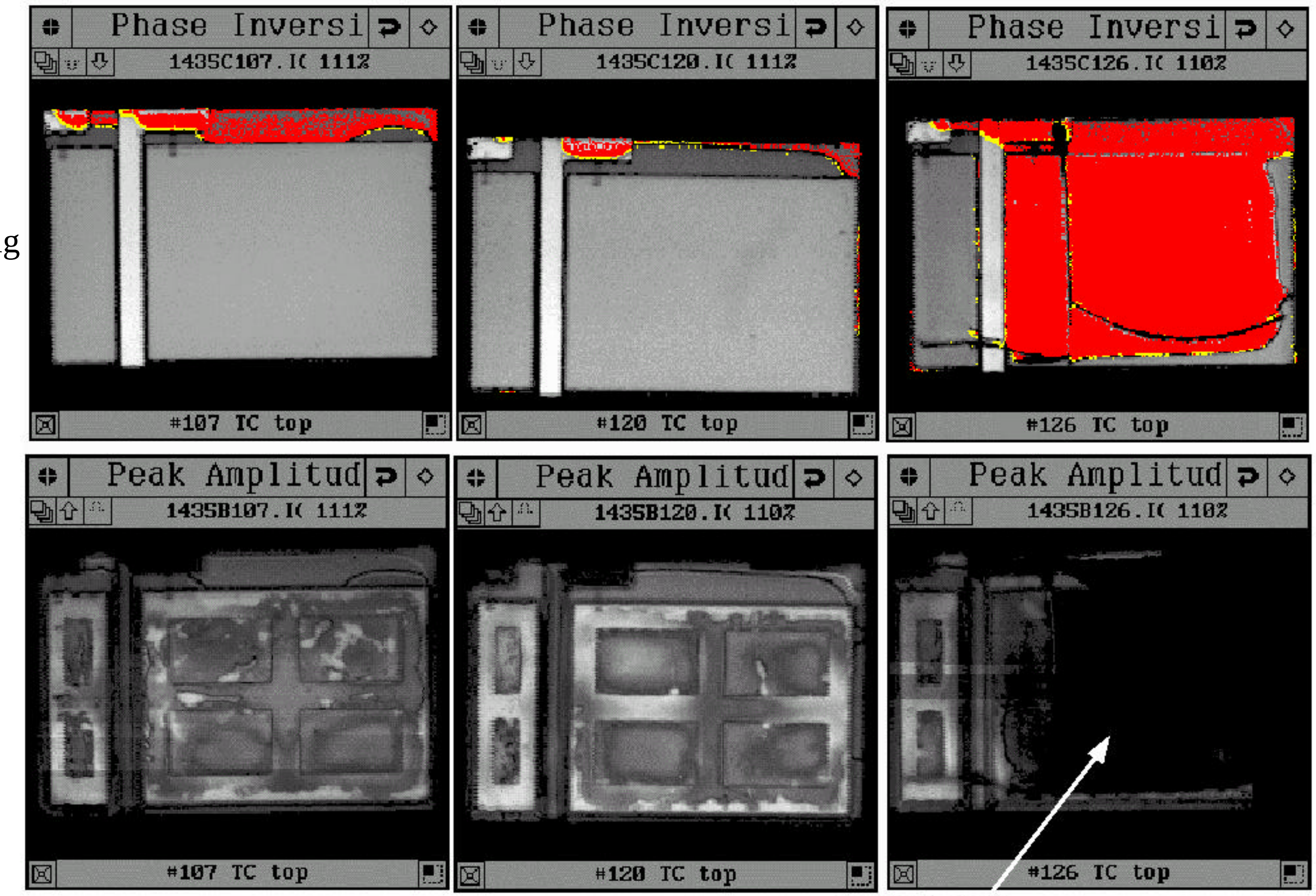
Serma Technologies (France)

Acoustic Microscopy after thermal cycling (40 cycles, -30°, + 80° C)

Delamination/Cracking
Epoxy/Carrier/Wafer

Die Attach
(no changes w/ cycling)



no signal due to
epoxy/die delamination

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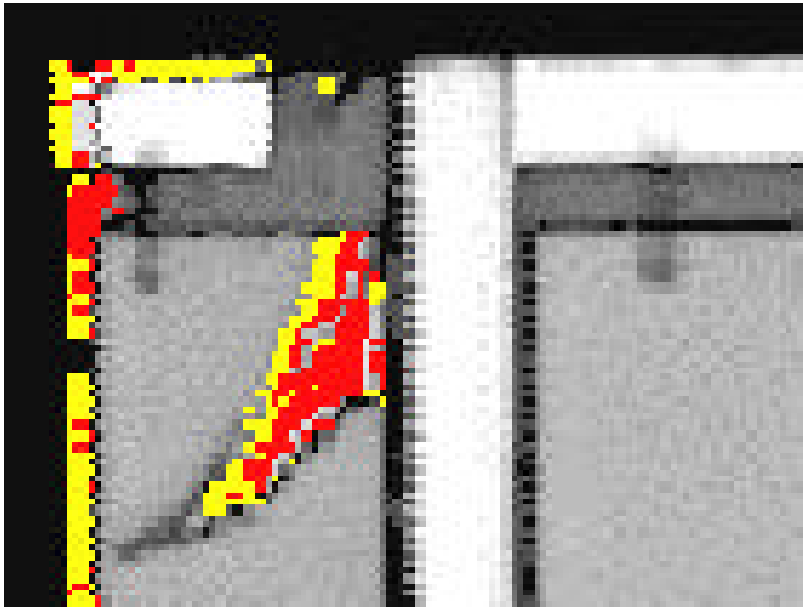
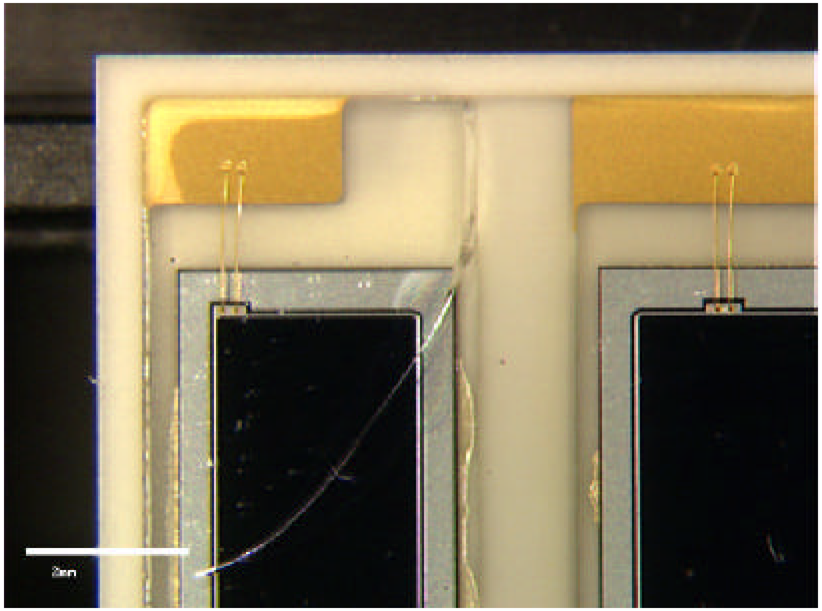
Serma - Acoustic / Optic Microscopy

- **Acoustic Microscopy**



- **Optical Image**



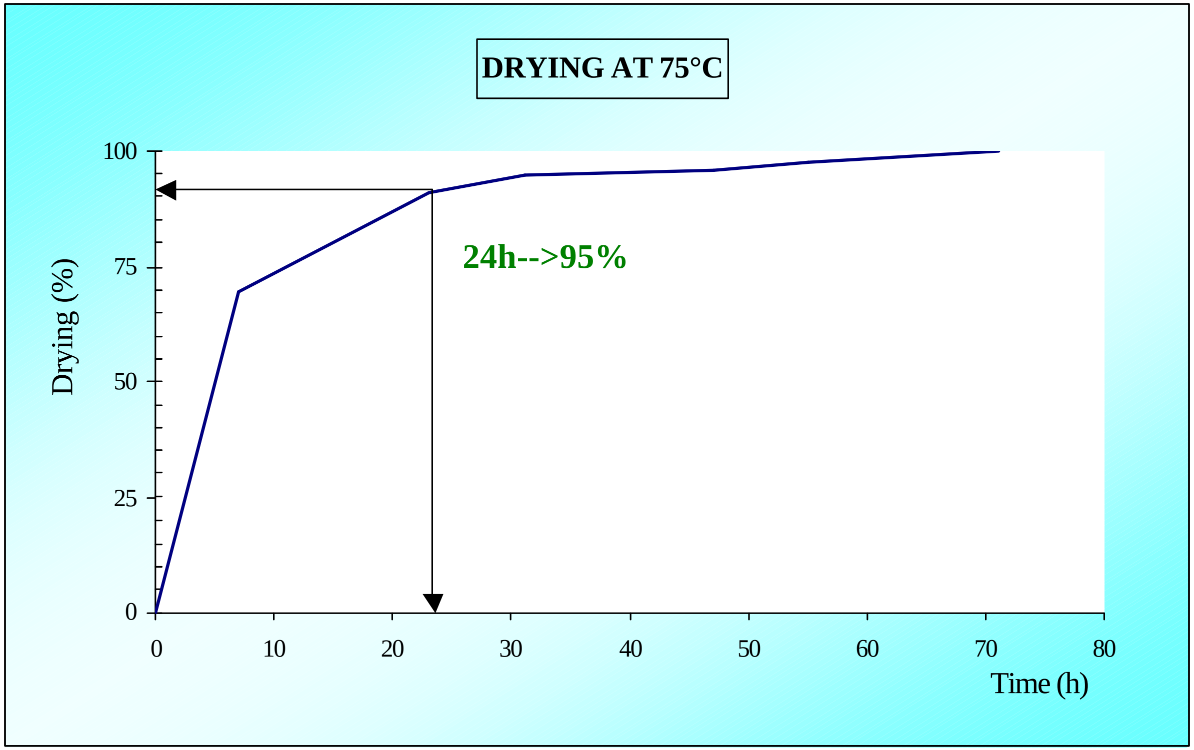
Serma: Moisture and Drying

- The glass transition temperature (Tg) of the DPD window measured is:

  98.4+-1.5°C (curing at 133°C)

  Note: the epoxy supplier give : 85°C (with a curing at 90°C)

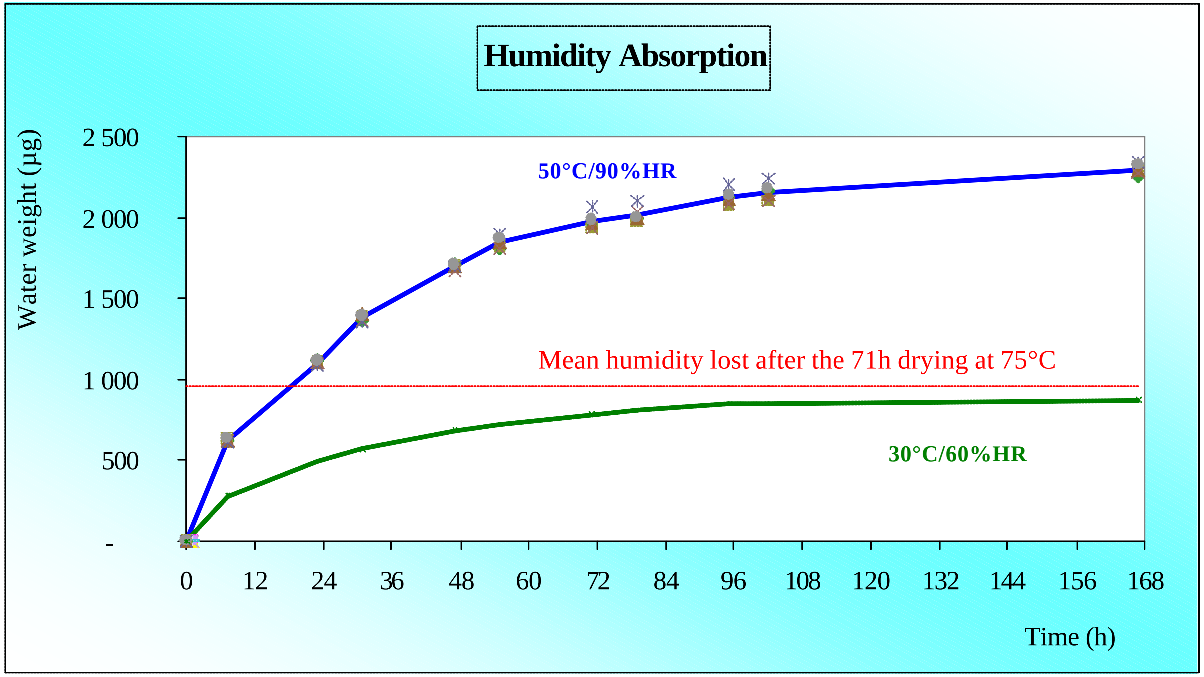
- DPD drying: (~900µg of water in DPD)



Serma: Humidity absorption

- The among of water absorbed by the epoxy resin depend of the environment condition:

1. Line condition: 30°C 60%R.H. 900µg
2. Top condition: 50°C 90%R.H. 2300µg



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Serma: Temperature stress

- **Thermal Cycling:**

Temperature slope: 1 to 2 °C/mn

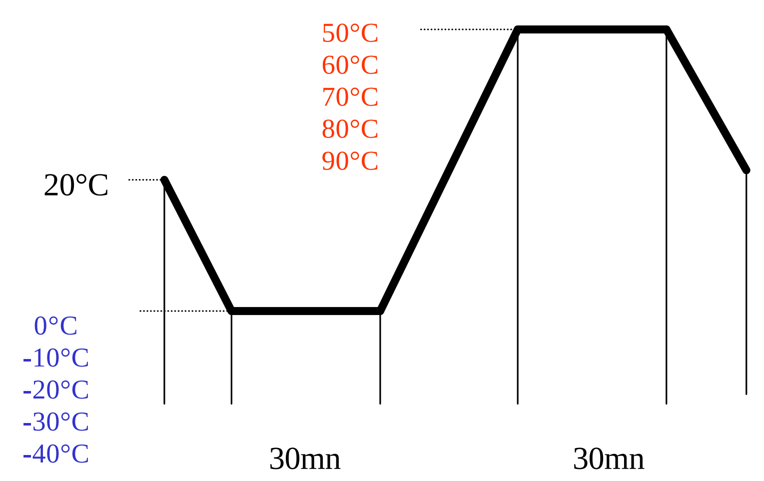
5 steps, sample remove

- **Low temperature: -40°C 168h**

  using 0 to 50°C T.C. DPDs

- **High temperature: 90°C 168h**

  using –10 to 60°C T.C. DPDs



Acoustic Microscopy results: Cracks (c) Electrically dead(d)

		Delamination at interface					
Steps	**Die attach**	**Epoxy/die**			**Epoxy/ceramic**		
Initial	No	No			No		
Steps		Dry	30°C/60%RH	50°C/90%RH	Dry	30°C/60%RH	50°C/90%RH
After T&H	No		No	No		No	No
After TC 0°C/50°C	No	No	No	No	No	No	beginning
After TC -10°C/60°C	No	No	No	No	No	No	beginning
After TC -20°C/70°C	No	No	No	No	No	No	Partial
After TC -30°C/80°C	No	No	No	c Complete d	Partial	Partial	c Partial d
After TC -40°C/90°C		Partial # 108,109		1 c, 2 d	Partial all DPD		
After 168hrs -40°C		No	No	c Partial	No	No	c Partial
After 168 hrs 90°C		No	No	No	No	No	beginning

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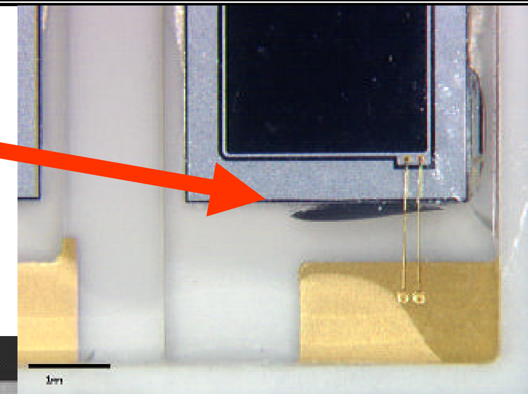
Serma: Elect. & Optical Measurements

Four of the 24 test DPD had electrical failure on diode A or B:

- **Investigations of the 4 electrically dead DPDs show that delamination and cracking of the optical epoxy resin applied tensile and shearing forces on the wire bonds of the Si die to the carrier.**
- **These forces ultimately broke the wire bonds resulting in open circuits.**
- **A potential exists for intermittent electrical connections where thermally-induced stresses on delaminated devices make/break these wire bond connections.**

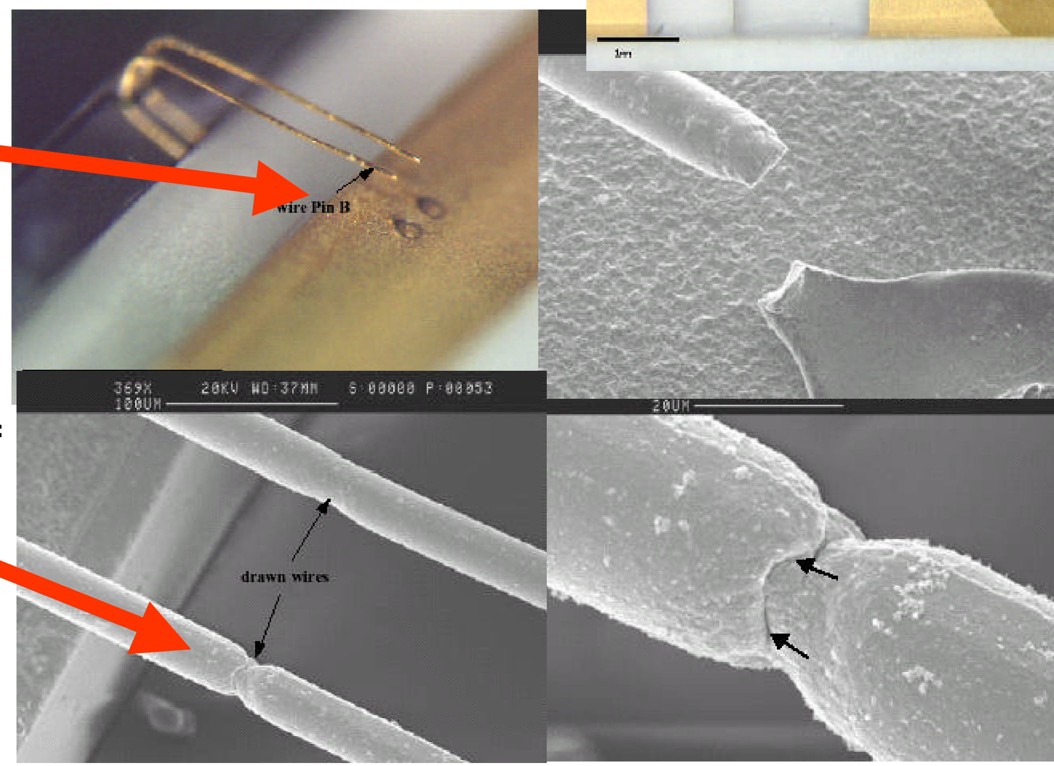
Serma: Wire Bond Failures (DPD #108)

Delamination and cracking near wire bonds causes tensile and shear stress on the bonds.



Bond broken at heel of the weld for diode B

Wire drawn in connection of diode A



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Dual PIN Photodiode Cracking

- **The Evidence**
  - Cracking begins in high stress areas – corners of carrier, corners of Si die.
  - Correlated with ΔT range of temperature cycling and number of cycles
  - Some correlation with H_2O-loading of epoxy before cycling (ie. humidity control before testing) but counter evidence as well.
  - Some correlation with rate of change of temperature in thermal cycling
    - > 2 deg/min shows catastrophic cracks
    - ~ 0.3 deg/min shows micro cracks.
- **Potential Solution: Process control**
  - Die attachment epoxy coverage to edges of die
  - Cleanliness after die attach process, before optical epoxy application
  - Die cutting method and edge burrs that could create stress points
  - Control of optical epoxy encapsulation to insure expoxy has good coverage and attachment at corners.
  - Optical epoxy viscosity control
  - Moisture control during processes, storage and shipping.
- **Potential Solution: Polishing of epoxy surface – don't do it.**
  - Polishing of epoxy is performed to achieve a flat bonding surface
  - Potentially causes stresses in the epoxy
  - (but failures seen in both polished and unpolished samples)

NRL/ CEA Concerns

- Since Hamamatsu does not see these epoxy cracking problems to the same degree, we do not have a good understanding of the underlying cause
  - Process variation?
  - Aging problem?
  - Test parameter and controls differences?
- Epoxy cracking is considered the weakest link in the diode manufacture and becomes worse during thermal cycling
  - Delamination is the start of the cracking problem.
- The polishing process may be contributing to the stress of the epoxy and is not a clear requirement any more.
  - Propose relaxing the epoxy surface flatness requirement to be ~150 micrometers.
  - Issue is to verify that this has no adverse effect on bonding the diode to CsI.

Requirements

- Thermal Cycling: 60 cycles
  - \- 30 deg C, + 50 deg C
  - 1 deg/min rate of change (flight rate of change is < 20 deg/hour)
  - 30 minute dwell at extremes
- Moisture Intake: 168 hrs at 50 deg C, 50% relative humidity storage
- Steady-state life test: 1000 hrs at 60 deg C

Reference Table 7 of Dual Photodiode Specification.

Thermal Cycling Tests at NRL (3)

- **Sample 5: 10 bare S8576 diodes – Oct 2002**
  - **Spring ’02 shipments, lot 2B**
  - **Test to qualification spec proposed by Hamamatsu**
  - **Dry for 24 hours at 85 deg C**
  - **-30C to +50C, 1 deg per *minute*, 30 minute soaks; 60 cycles**
  - **Dry nitrogen purge, rapid but unmeasured flow rate**
  - **Diodes placed on wire mesh platform away from chamber walls**

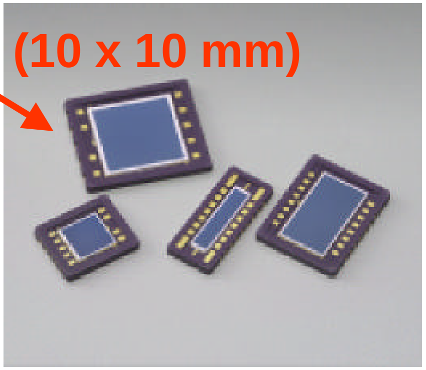
- **Results:**
  - **9 with severe cracking of resin**
  - **1 with delamination of resin from ceramic.**

⇨ ***Alternative plan needed***

Alternative DPD Optical Windows

- Silicone Elastomer – Hamamatsu standard process (S5100 series diodes)
  - Purchased 40 commercial parts (S5107)
  - Thermal cycling to date shows no delamination or cracking (60 cycles)
  - Bonded 4 diodes to CsI for bond strength tests
  - Ordered 10 DPD with this silicone optical window. Delivery expected next week.
- Softer version of current DPD optical window epoxy. Hamamatsu is experimenting with this.
- Serma/CEA investigating alternatives including glass beads mixed in w/ epoxy.
  - 10 DPD with no encapsulant have been ordered for these tests.
  - CEA ordering bare commercial diodes to test first
- DC93-500 silicone elastomer – use the same material as for the bond of diode to CsI.

S5107 (10 x 10 mm)



Issue: Silicon die has a very thin passivation on the surface. Hamamatsu is concerned about long-term leakage current problems developing with encapsulants they have not studied.

Qualification Acceptance Criteria

- Optical properties are still within specification
- Electrical properties are still within specification
- Epoxy inspection at x20 magnification
  - No cracking
  - No micro cracks longer than TBD mm
  - No delamination
- Void free die attach verified in qualification testing

Dual PIN Diode Summary

- **Alternative silicone elastomer from Hamamatsu looks promising in early thermal and bonding tests**
- **Other solutions will take significantly longer to develop and test.**
- **There are only 15 DPD ceramic carriers left at Hamamatsu for other test configurations**
- **We need to initiate DPD procurement for flight units in November to maintain FMA and FMB delivery schedule.**
- **Mitigation to delay of optical window material decision is possible with procurement of only the tooling for the ceramic carrier and the Si die masks.**
  - **This modest procurement (~ $65k) would provide 2 months relief in decision and provide 50 prototype diodes.**
  - **Assumes that ultimate decision will not require change in the ceramic carrier design.**